



GNSS Survey Report

New York Statewide
LiDAR Acquisition
Lot 17

2017 Southwest 17 LiDAR
Ground Control Survey Report

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Axis Project Number 13367-1706

Date: 05/30/2017
NYS Edits on Page 12: 8/8/17

NY17 Southwest 17 LiDAR Primary Gound Control Folder Explanation and Inventory

NY17 Southwest 17 LiDAR– GNSS Survey Report- This is the primary file forming the narrative of the survey report and contains descriptions of work areas, methodologies employed and contains a listing of final coordinate values and a coordinate analysis of our positioning vs. published NGS. Page three of the GNSS Survey Report is a table of contents breaking the file structure of the work areas down and listing report file names and equivalent deliverable features.

The deliverables are grouped into four subdirectories as follows:

NGS Control Folder- Contains NGS datasheets for all terrestrial and CORS/NYSNet CORS stations used for RTN control or validation

RTN Dataset Folder- Contains four PDF format RTN reports, three of which are listed in the RTN dataset section of the table of contents. The fourrth PDF report is a coordinate system report listing coordinate system definition values.

Field Data Folder- Contains the field data files of the observations in Leica proprietary format

Datasheets Folder- Contains field observation datasheets of the LiDAR data ID points.

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RTN Dataset Folder

Field Data Report

Mean Coordinates and Differences-Field Data Report

Observation Report/Concise Tabulation of GNSS Observations

Point Report/Concise Tabulation of Final Coordinates/PID # Match

GNSS Survey Report Narrative

May 30, 2017

State of New York
Office of Information Technology Services,
GIS Program Office
10B Airline Drive
Albany, NY 12235

Attn : Francis M. Winters, Director of GIS Programs

Re: GNSS Survey Control Report-Primary Control
Axis Project # 13367-1706, NY South West Area 17 LiDAR Project Area, New York
NY Contract #C300036

Please find enclosed a series of reports, diagrams and other supporting information that forms the formal GNSS Survey Report for the referenced project. Additionally, we have included a narrative of the methodology, techniques and technical details about the equipment and technology utilized to execute the project.

Process Summary

AXIS GeoSpatial, LLC was authorized to collect airborne LiDAR for the counties of Chautauqua, Cattaraugus, Wyoming and parts of Allegany and Genesee in the spring of 2017. Based on mission planning by the project Certified Photogrammetrist, a map was provided to me for evaluation and GNSS Survey planning which contained the planned flightlines, proposed ground control points and proposed check points. Based on available local control, the site's proximity to high order NYSNet CORS stations and the number and related geometry of surrounding Real-time Network base stations, as well as the numerous benefits of using a Real-time Network positioning solution, AXIS moved forward with mobilization for the project and configuration of my equipment to utilize The New York NYSNet Real-time GNSS Network. Based on the approximate locations of the ground control and check points needed for the dataset, I field selected a final location for each point based on a number of factors including safety concerns, visibility of the ground control point from the plane in its flight path, satellite obstructions, multipath sources and ground surface conditions. The raw point cloud was used in the field to make final selections of the ground control points based on return intensity, and suitability of the feature for occupation. Positioning was conducted using a hybrid methodology, internally referred to as Real-time Static, which involves using a tripod or bipod mounted GNSS antenna/receiver to collect multiple sets of data at a one (1) second intervals, typically for one (1) minute per set, for each survey point. Traditional Real-time Kinematic survey practice is to take a single measurement of a point, using a rover pole. We have found that by collecting multiple sets of data on each point using a stabilized setup, accuracy and precision of the ground control points is optimized. As redundant check to all of the measurements, we measured all of the points, including the NGS control points and the survey points up to five times per occupation, with each observation being made after breaking the fixed solution and forcing re-resolution of the positioning ambiguities by the receiver. Per NYDOT specifications, all GNSS survey control points were re-occupied a minimum of twenty minutes later to confirm positioning quality with a different satellite constellation configuration. A report is attached showing the observation times, measurement statistics, and other pertinent information, including a spreadsheet detailing observed variances from published control. Results using multiple observations, and time offset re-occupations are exceptional, as borne out by the statistical analysis.

Real-time Network Positioning

UTM Zone 17 coordinates for this project were determined using the Real-time Network (RTN) NYSNet, verified with the measurements to monuments found in the National Geodetic Survey Control Point database. The use of an RTN for geodetic control involves the collection and correction of ionospheric, tropospheric, satellite clock errors and orbital errors from multiple permanent control points surrounding the observation site, resulting in high precision positional data, based on correction data from all the surrounding stations, and a positioning vector measurement from an optimized base station, generally the

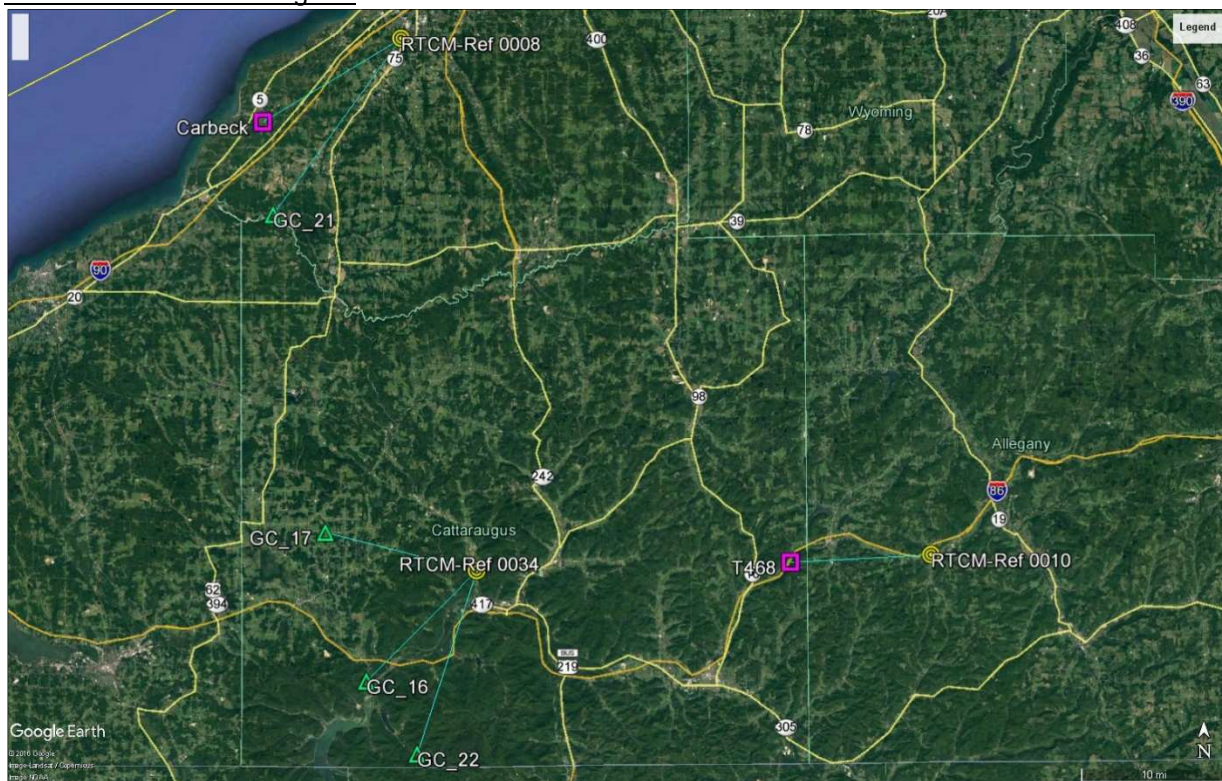


closest to the rover. The control points of this network are NY State Continuously Operating Reference Stations, NYSNet CORS Stations and National Geodetic Survey Continuously Operating Reference Stations or NGS CORS, and the resulting measurement vectors between the GNSS receiver and network station are direct measurements to existing, high order physical monuments, which have been vetted, documented and distributed by the State of New York and the National Geodetic Survey from their online control databases. Additional measurement data was also collected during the survey fieldwork to other high order, local national geodetic survey monuments as a supplemental verification of positioning quality.

A real-time reference frame based positioning system by its very nature will not always match published positions of ground control points, regardless of their adjustment status, due to their original measurement methodology and accuracy classification, time passage since original observation, exposure to the elements, forces of nature and the deliberate or accidental injury to their integrity by man.

The project area contains a fairly well distributed, GNSS observable NGS control point framework, and control check in was conducted to points within the immediate project area.

NYSNet RTN Vector Diagram



Primary RTN Control Stations:

NYSNet NYHB Ref008
NYSNet NYSM Ref0034
NYSNet NYFS Ref0010

HAMBURG CORS ARP (DI0458)
SALAMANCA CORS ARP (DI0620)
FRIENDSHIP CORS ARP (DI0454)

NGS Control Stations:

CARBECK NC0522
T468 NC0828

Recovered as described
Recovered as described

Positional comparisons for both work areas are available for review, as well as detailed observations reports in the Static Mission Reports sections of this GNSS report.

Fieldwork Mobilization Dates: May 25th and 26th, 2017

RTN Field Equipment

GNSS receiver technical data: Leica GS-15- Geodetic GNSS receiver/antenna (GPS L1/L2/L2C/L5 and L1/L2 GLONASS frequencies), Serial #1505760 firmware v. 5.61
Leica CS-20- Serial #2490713 Controller firmware/Captivate v. 2.04

Field procedure/methodology: GNSS- Multiple, redundant, multi-set observations with offset occupation times and individual ambiguity resolutions, using NYSNet real-time network.

Field Equipment Adjustment/Calibration/Field Checks

Laser plummets were field checked at each setup, using the precise level plate level bubble and a two position check routine. Rotation of a laser plummet will immediately reveal any defect in the internal structure or alignment of the laser.

Instrument heights were measured using a device called a height hook, which makes a direct, vertical reading of the instrument height without concern for slant height or other problems. The height hook reading is made in millimeters, which offers an exact, high precision measurement.

No change or adjustment to any field equipment was necessary throughout the duration of this project.

Office Software

The GNSS receiver and its controller hardware interface via field software called Leica SmartWorx, which provides a user interface and workflows for collecting data, analyzing datasets, selecting results and performing other calculations, including QA/QC analysis, exporting of data and reports and organizing project data. Office software used is the full suite of Leica Geo Office, Version 8.4 (current) and Leica Infinity Version 2.1 (current), which provide an interface for downloading data, generating reports and performing calculations, analyzing data, and organizing and printing project reports. Additional analysis was performed using Microsoft Excel 2010, AutoCAD Civil 3D 2016, AutoCAD Map 2016 and the Google Earth extension of Leica Infinity.

RTN Observation Methodology

Every point established during this project has a final position based on a number of individual observations at different times, each with a fresh ambiguity resolution. The total number of observations on a point is based on the observer's analysis of the quality of those observations, known network geometry and the consistency of the results as a group. Positioning points using a number of observations helps to identify fluctuations in positioning due to base to rover vector length, varying satellite geometry due to observation window obstructions, and network cell station geometry/spacing and availability. The individual observation dates and times can be reviewed in the GNSS Observations Report of this report, and the actual detailed observation vectors, geodetic positions, Dilution of Precision values, observation inclusion and exclusion, and related averaging information can be reviewed in the Field Book Report section of this report. Averaging of the individual observations to obtain the final position for a point is weighted by the software, based on the positional quality of each observation.

Survey point numbers were matched to the Photo ID point numbering scheme, allowing a reviewer to follow the progress of the observations as they were made on both photo control points and to document the sequencing of check in observations to NGS and local survey control points. The correlation between survey point number and the actual Photo ID number is documented in the tabulation of the Final Project Control values on page 12.

QA Testing of RTN Observations

Quality Assurance testing of the RTN data was accomplished via statistical analysis of the observations on each point, as well as using two instrument heights during observations to confirm height hook readings.

A table comparing redundant observations on primary control points and NGS control points is available in the Control Analysis section of the report.

Statistical Analysis & Quality Reporting

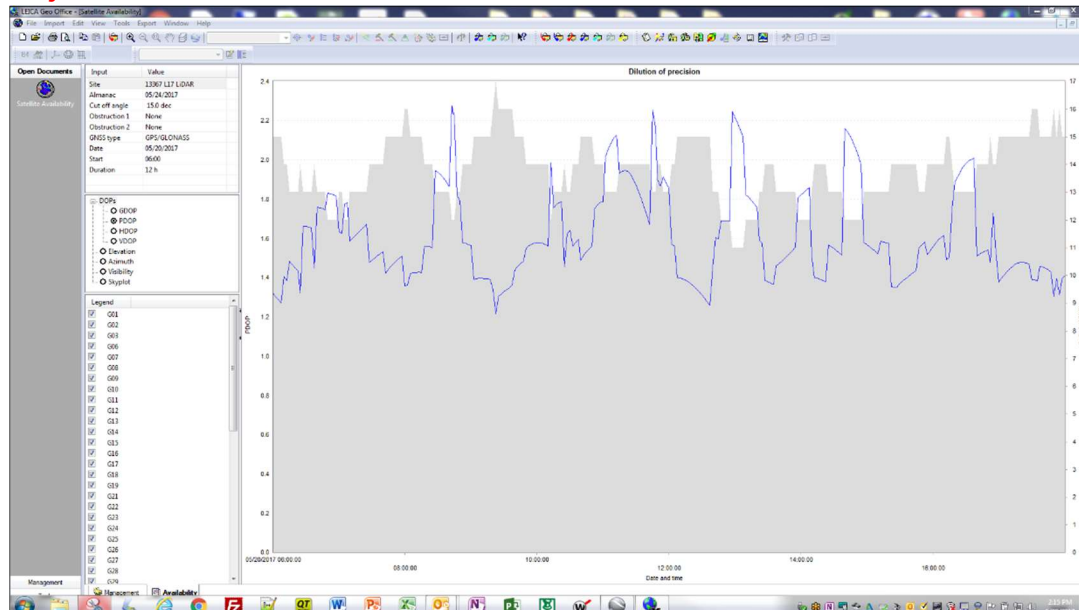
A table showing the statistical analysis and positional quality of the NGS control points is available in the Control Analysis Table starting on page 11 of this report.

Satellite Geometry and Observation Planning

The following charts were used to schedule and manage the point observation schedule during the fieldwork. Point locations were selected in the field to optimize satellite visibility, avoid multipath sources and provide the most accurate control network for the digital aero-triangulation process. The observation planning site for this project was based on the approximate centroid of the work area, as final visibility of the satellite constellation is dictated by the individual site conditions and obstructions. Since the constellation changes daily, with satellites arriving approximately four (4) minutes earlier each successive day, the observation planning was revisited every two weeks to maintain a current status on the timing of spikes in DOP values. The chart is used in real time during the work day to optimize observations and avoid DOP spikes. The planning chart windows were restricted to working hours to enhance detail.

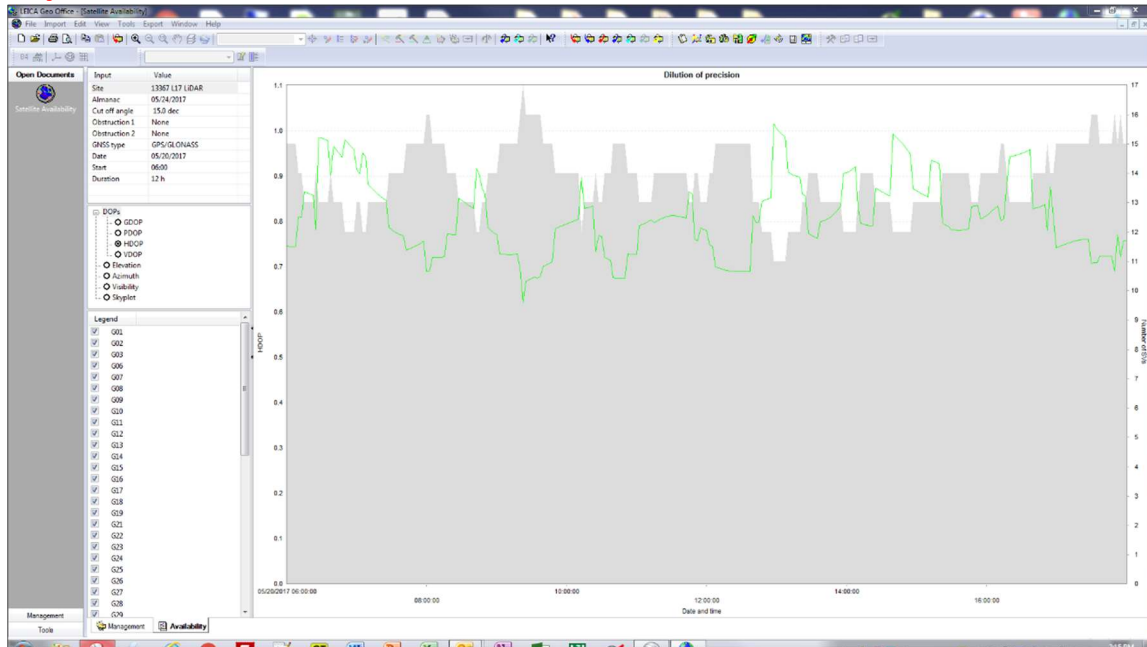
Samples of the planning charts for the project are presented below.

Project PDOP Chart



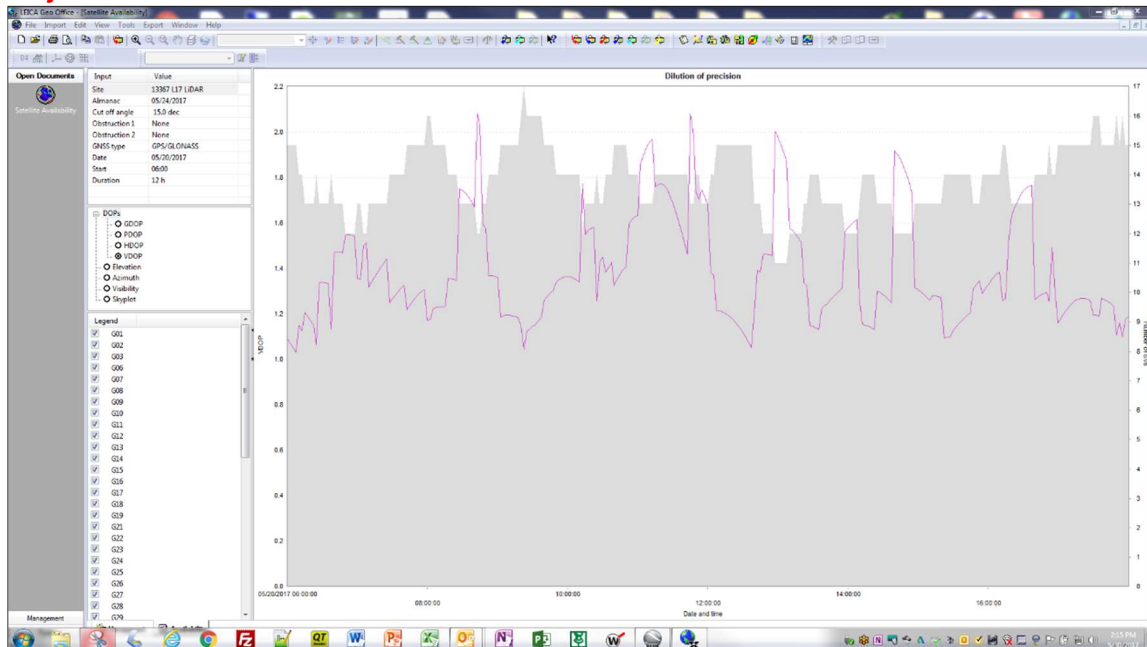
The Positional Dilution of Precision is a numerical gauging of the quality of positions yielded by GPS and GLONASS satellites at a particular time, without consideration of ground conditions. Actual PDOP will vary from the planned values based on field conditions, such as obstructions by buildings, trees and terrain.

Project HDOP Chart



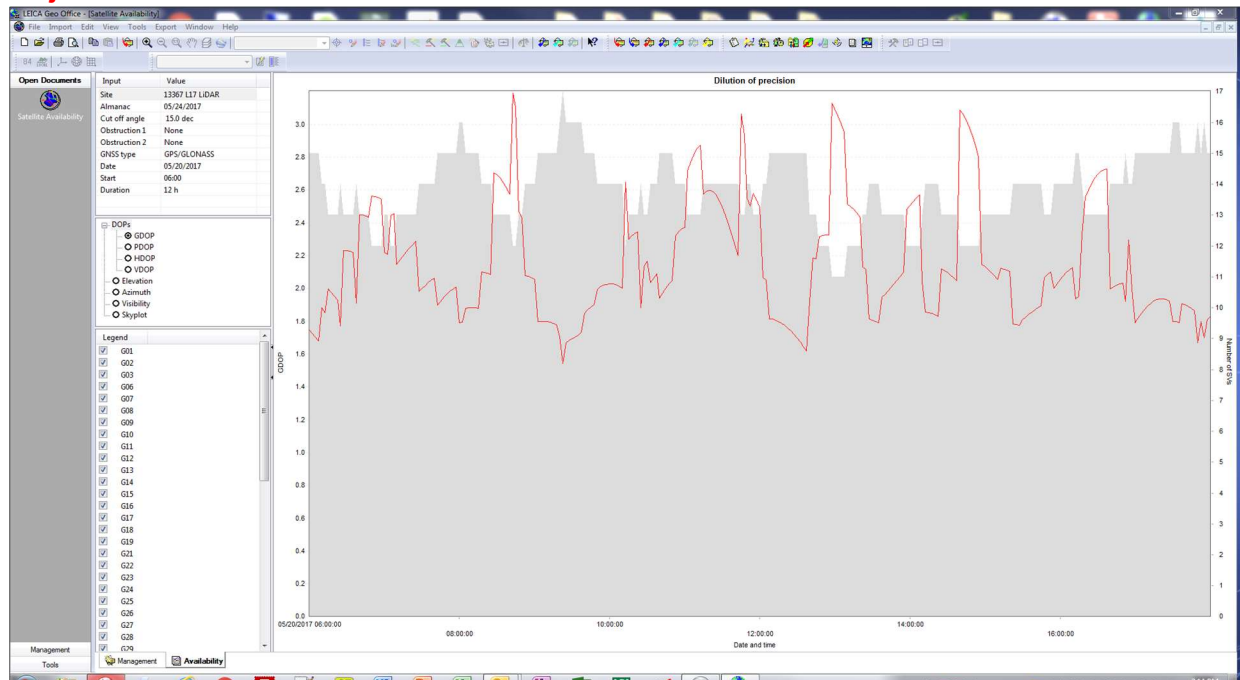
The Horizontal Dilution of Precision (HDOP) value is a numerical gauging of the quality of 2-D horizontal position yielded by GPS and GLONASS satellites at a particular time, without consideration of ground conditions. Actual HDOP will vary from the planned values based on field conditions, such as obstructions by buildings, trees and terrain.

Project VDOP Chart



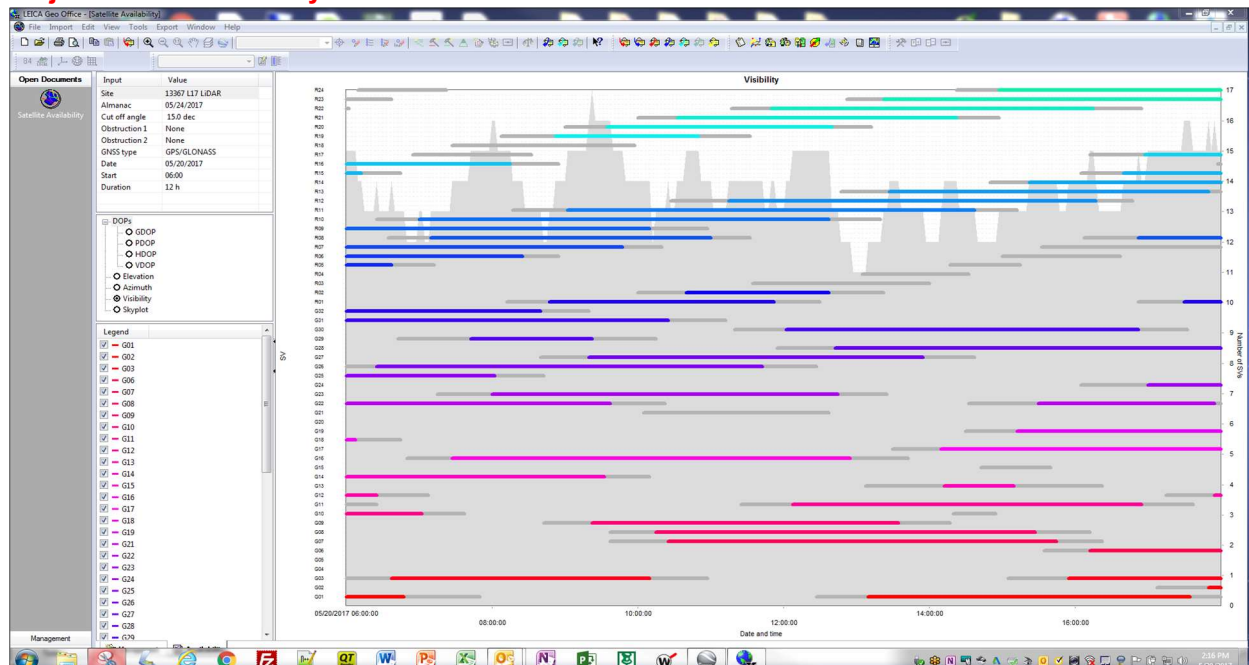
The Vertical Dilution of Precision (VDOP) value is a numerical gauging of the quality of 1-D vertical position yielded by GPS and GLONASS satellites at a particular time, without consideration of ground conditions. Actual VDOP will vary from the planned values based on field conditions, such as obstructions by buildings, trees and terrain.

Project GDOP Chart



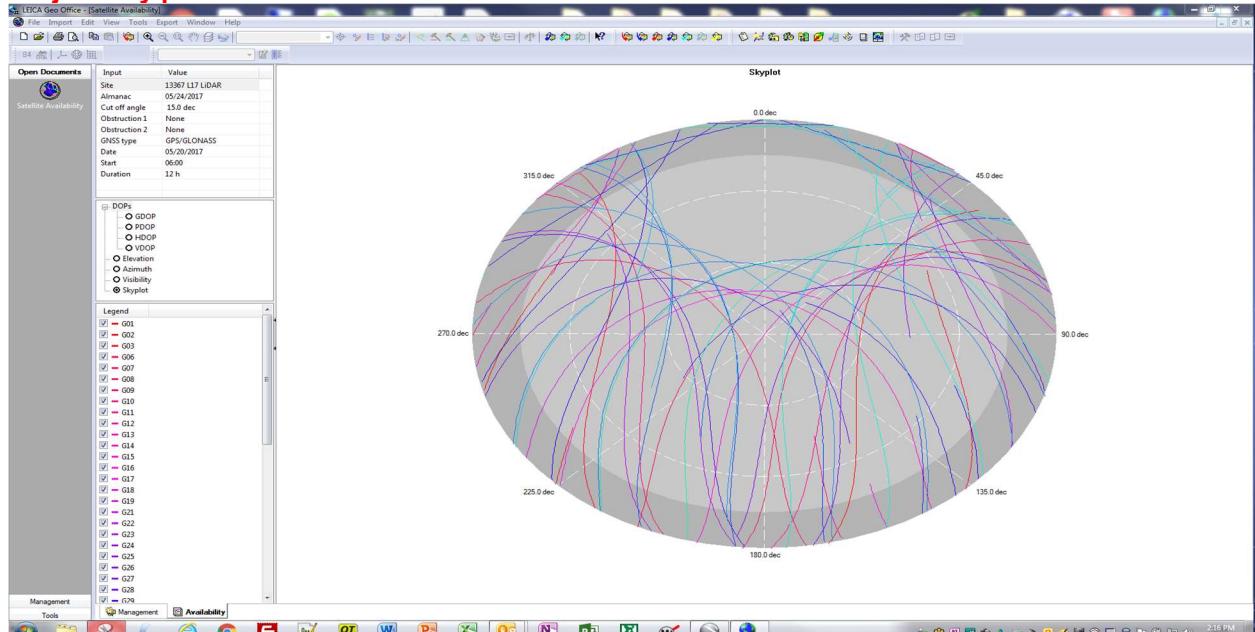
The Geometric Dilution of Precision (GDOP) value is a numerical gauging of the satellite geometry yielded by GPS and GLONASS satellites at a particular time, without consideration of ground conditions. Actual GDOP will vary from the planned values based on field conditions, such as obstructions by buildings, trees and terrain.

Project Satellite Visibility Chart



The Satellite Visibility Chart is a graphical representation of the time that individual satellites are available for observation, allowing planning for observations based on satellite constellation density and common time. The satellite visibility will vary from the planned values based on field conditions, such as obstructions by buildings, trees and terrain.

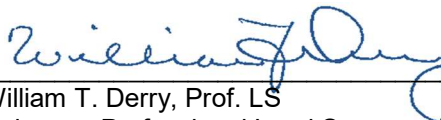
Project Sky plot Chart



The skyplot chart is used in mission planning to assess satellite location and trajectory during a particular window in time that will be used to observe GNSS satellites. The chart shows day long trajectories of available satellites. During actual planning, the planned start and stop times of the observation are used to restrict the plotted trajectories to only their path during the observation. Satellite observability is further restricted by site obstructions.

Responsible Charge

All of the field work and GNSS computations for this project was conducted under my supervision, a Professional Land Surveyor, following NYDOT Photogrammetric Control Procedures, National Geodetic Survey Guidelines for GNSS Surveying using Real Time Kinematic and Real Time Networks and FGDC Guidelines for GPS Positioning.



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Date: 05-30-2017

13367-1706 NGS QA Control Analysis Worksheet				
Horizontal Datum:	UTM 17N			
Vertical Datum:	North American Vertical Datum of 1988 derived using Geoid 12B			
Units:	Meters			
Axis Geospatial Survey Points- RTN				
Pt#	Northing	Easting	Ortho Ht.	Code
1	4722185.848	661370.887	215.432	Carbeck
6	4675291.431	720355.288	452.046	T 468
NGS Datasheet Values				
PID	Northing	Easting	Ortho Ht.	Name
NC0522	4722185.836	661370.873	215.423	Carbeck
NC0828	4675291.417	720355.285	452.062	T468
Comparison Matrix (RTN Dataset vs. NGS Published Data)				
	▲ Northing	▲ Easting	▲ Height	
1 vs. NC0522	0.012	0.014	0.009	
6 vs. NC0828	0.014	0.003	-0.016	
	0.0010500	0.0055000	0.0123000	Std. Dev.
	0.01370	0.01400	0.00860	Max.
	0.01160	0.00300	-0.01600	Min.
	0.01265	0.00850	-0.00370	Average

Southwest17 LiDAR
 UTM Zone 17, meters

SVY PT#	Point Id	Northing	Easting	Ortho. Height	CQ 3D	CQ 2D	CQ 1D	SD North	SD East	SD Ortho. Ht.	Description
1	CARBECK	4722185.848	661370.887	215.432	0.005	0.002	0.005	0.001	0.001	0.005	NGS Disk
2	SW17GC21	4712051.037	662761.225	193.221	0.004	0.002	0.004	0.002	0.001	0.004	Mag nail set in asphalt
3	SW17GC17	4677368.716	669316.172	511.155	0.005	0.003	0.003	0.003	0.002	0.003	Mag nail set in asphalt
4	SW17GC16	4661170.689	674176.947	421.155	0.004	0.002	0.003	0.001	0.002	0.003	Mag nail set in asphalt
5	SW17GC22	4653310.184	679922.057	452.511	0.006	0.004	0.005	0.003	0.003	0.005	Mag nail set in corner of sidewalk
6	ROD T468	4675291.431	720355.288	452.047	0.004	0.002	0.004	0.001	0.001	0.004	NGS Disk